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1/77

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P01/7700 0.00-0218624.5

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Request for grant of a patent

(see the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

The Patent Office

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1.	Your reference	RMV/P400369
2.	Patent application number *(The Patent Office will fill in this part)*	0218624.5 10 AUG 2002
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	Emtelle UK Limited Haughhead Hawick TD9 8LF
	Patents ADP number *(if you know it)*	8220402001
	If the applicant is a corporate body, give the country/state of its incorporation	Scotland
4.	Title of the invention	SIGNAL TRANSMITTING CABLE
5.	Name of your agent *(if you have one)*	URQUHART-DYKES & LORD
	"Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)	ST NICHOLAS CHAMBERS AMEN CORNER NEWCASTLE UPON TYNE NE1 1PE
	Patents ADP number *(if you know it)*	00001644019
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number	Country — Priority application number *(If you know it)* — Date of filing *(day/month year)*
7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	Number of earlier application — Date of filing *(day/month/year)*

8 [illegible] statement of inventorship and or right to [illegible] of a patent required in support of this request? *(Answer "Yes" if:)*
a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body;
see note (d)

YES

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Continuation sheets of this form	
Description	11
Claim*(s)*	3
Abstract	DM
Drawing*(s)*	5-1 5

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Priority documents	
Translation of priority documents	
Statement of inventorship and right to grant of a patent *(patents form 7/77)*	
Request for preliminary examination and search *(patents form 9/77)*	
Request for substantive examination *(patents form 10/77)*	
Any other documents *(please specify)*	

11 I/We request the grant of a patent on the basis of this application.

Signature Date 08/08/02

Urquhart-Dykes & Lord

URQUHART-DYKES & LORD

12 Name and daytime telephone number of person to contact in the United Kingdom

Martin Vinsome - 0191 2618573

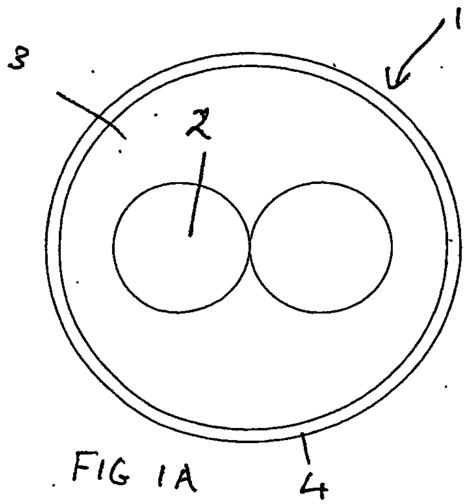


FIG 1A

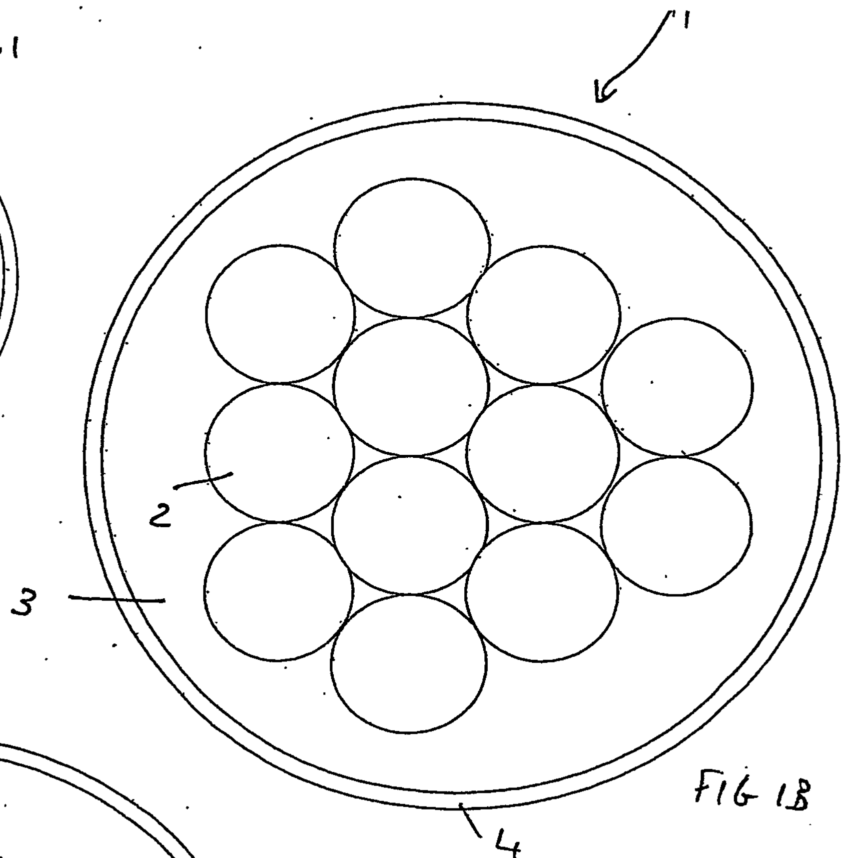


FIG 1B

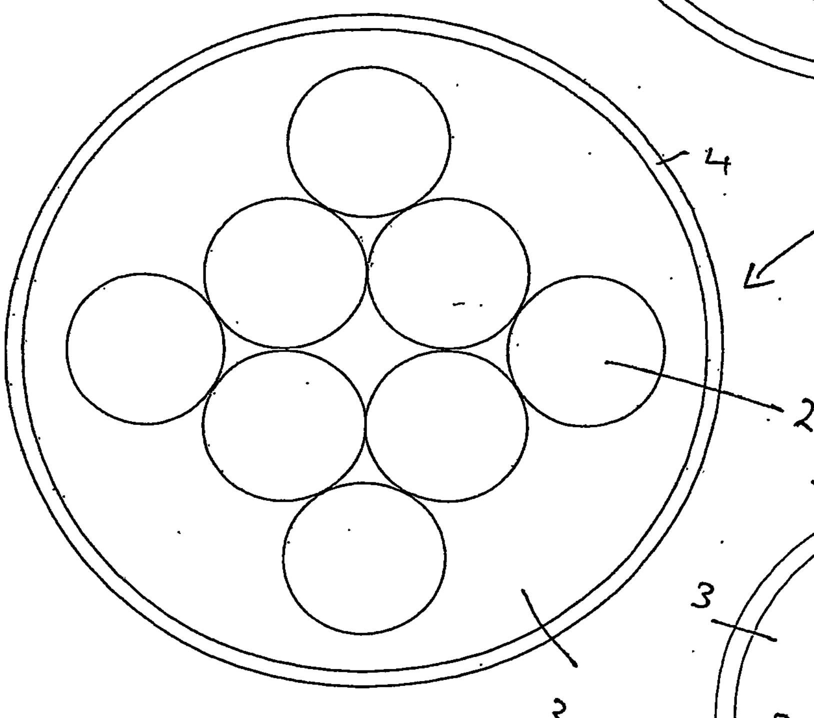


FIG 1C

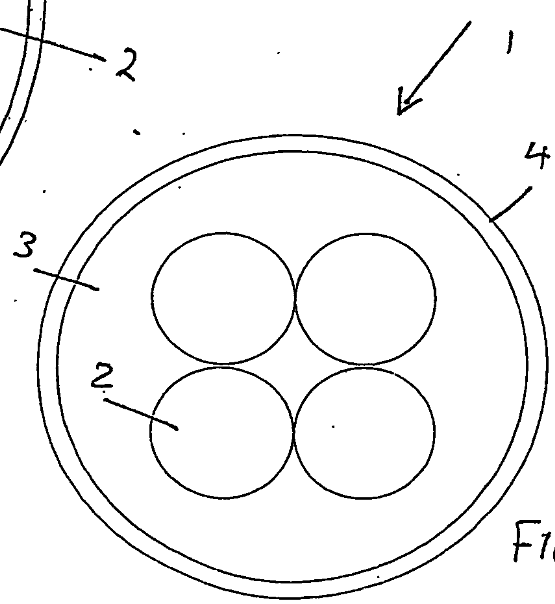


FIG 1D

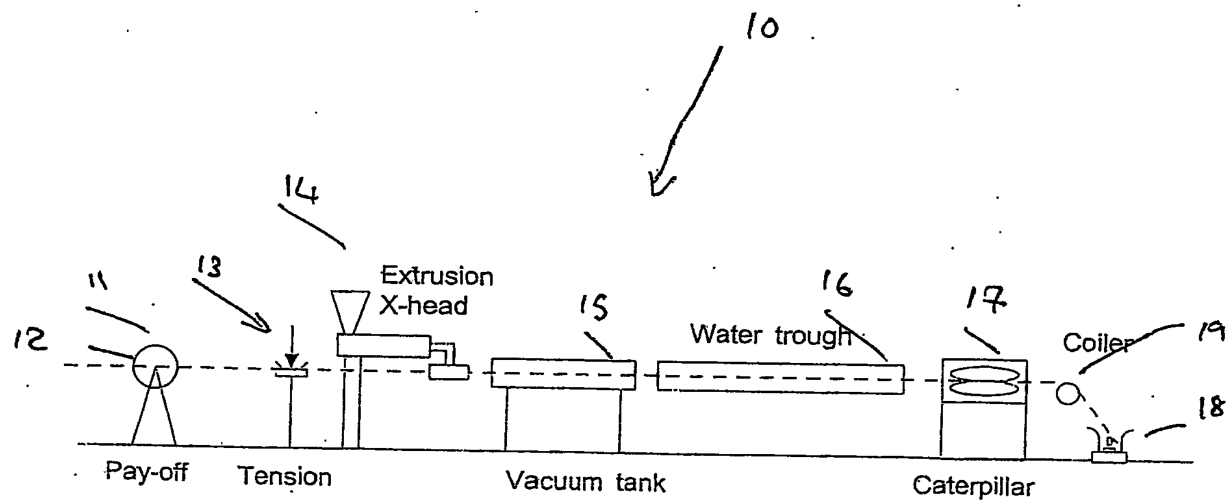
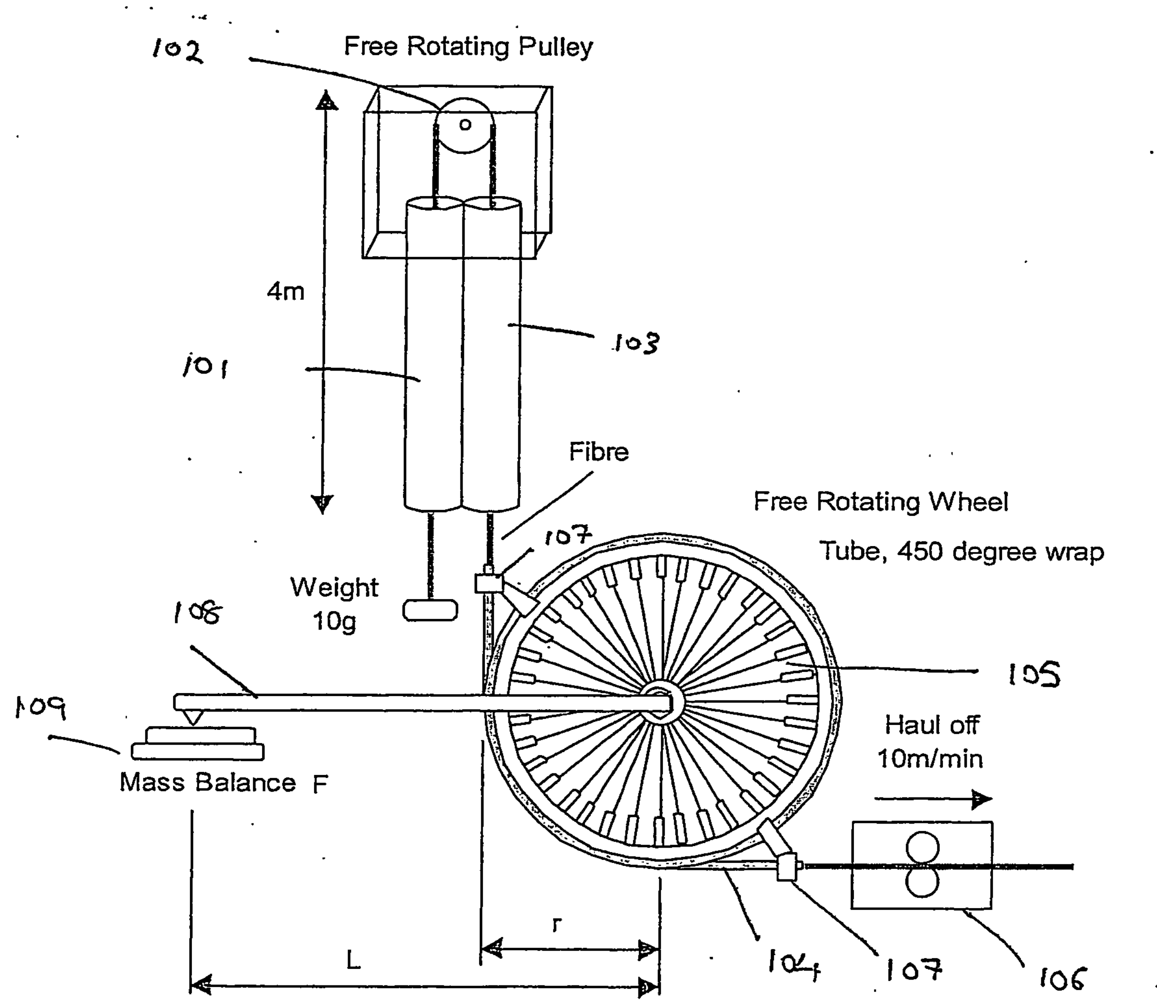

10
14
Extrusion
X-head
11
13
12
15
16
Water trough
17
Coiler
19
18
Pay-off
Tension
Vacuum tank
Caterpillar

FIG 2

Fig 3



Coefficient of friction is given by

$$\mu = \frac{1}{\theta}\ln\left[\frac{FL}{Tr}+1\right]$$

Where

θ	total wrap angle of tube (rads)
F	force recorded at mass balance (N)
L	Moment arm length of force F (m)
T	Weight lifted by fibre (N)
r	Bend radius of primary tube (m)

Fig 4a

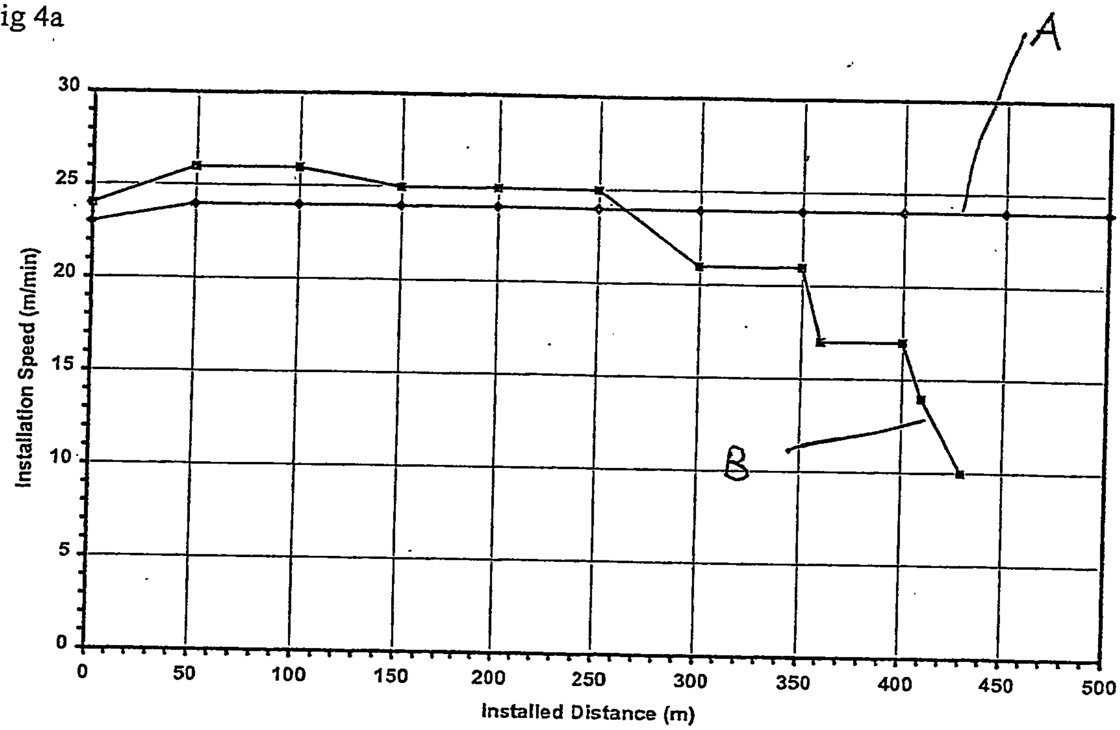

A
B
Installation Speed (m/min)
30
25
20
15
10
5
0
0
50
100
150
200
250
300
350
400
450
500
Installed Distance (m)

Fig 4b

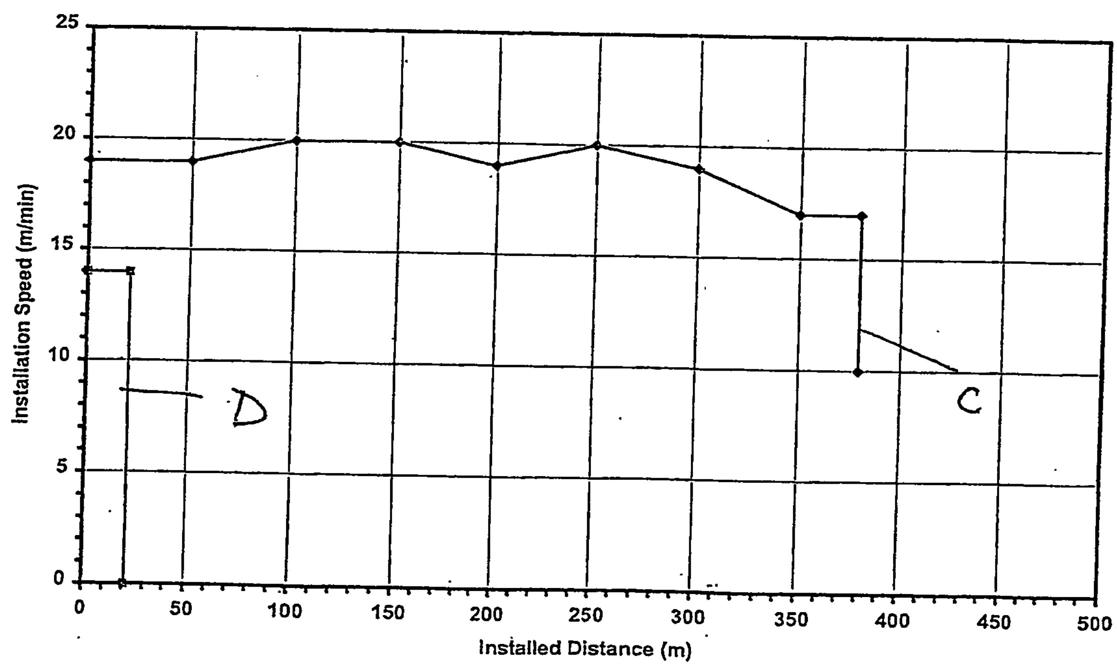
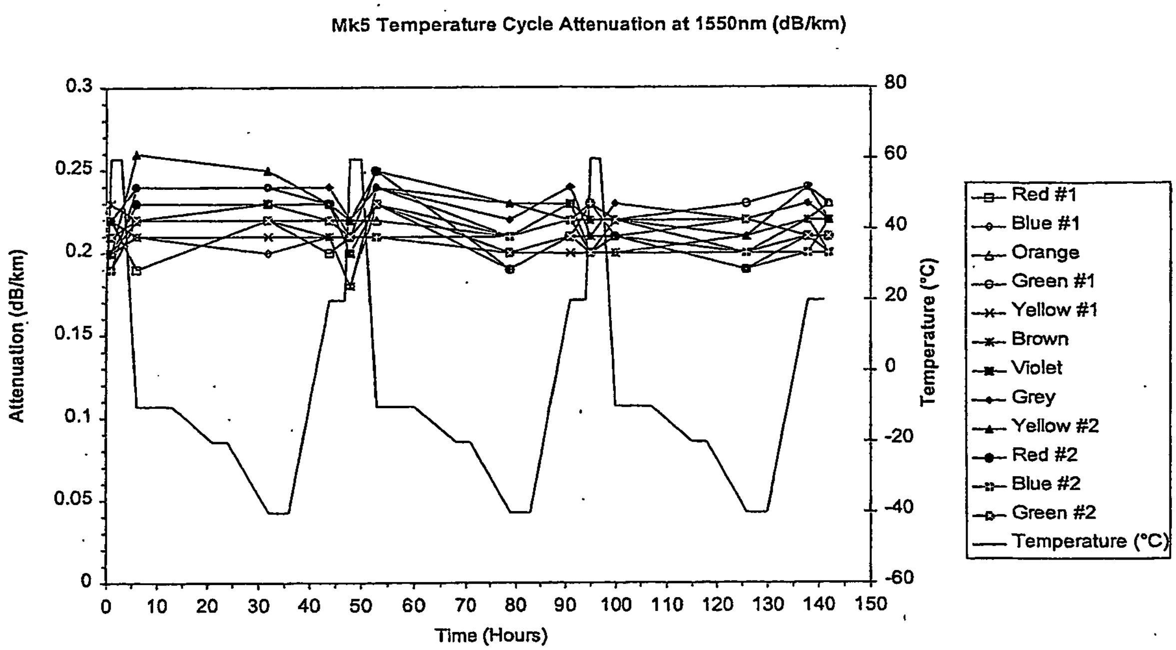

D
C
Installation Speed (m/min)
25
20
15
10
5
0
0
50
100
150
200
250
300
350
400
450
500
Installed Distance (m)

Fig 5


Mk5 Temperature Cycle Attenuation at 1550nm (dB/km)
Attenuation (dB/km)
Temperature (°C)
Time (Hours)
0.3
0.25
0.2
0.15
0.1
0.05
0
80
60
40
20
0
-20
-40
-60
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
Red #1
Blue #1
Orange
Green #1
Yellow #1
Brown
Violet
Grey
Yellow #2
Red #2
Blue #2
Green #2
Temperature (°C)

SIGNAL TRANSMITTING CABLE

The present invention relates to signal transmitting cables, and relates particularly, but not exclusively, to optical fibre cables to be installed in ducts by blowing.

Fibre optic cables have traditionally been constructed with relatively high fibre counts, typically 96 fibres, where the fibres are packaged within the assembly in bundles of 12 fibres and these fibre bundles are then packaged in a robust construction containing glass polymer reinforcement rods and metal elements to encapsulate and protect the fibres. Such cables tend to be relatively large in diameter and heavy. These cables are typically installed by one of two methods, either by installing a rope into the conduit into which the cable is to be installed, attaching the rope to the cable and pulling the cable into the conduit or by using a blowing and pushing machine. In the latter case a small hydraulically driven caterpillar is typically used to push the cable at the same time as compressed air is introduced into the conduit, assisting the installation process by creating a degree of fluid drag. These installation processes are well known and most of the European long distance telecommunications fibre optic cables to date have been installed using one or other of these methods. Installation of cables using this process requires large ducts up to 50 mm in diameter and very large compressors.

As the deployment of fibre optic cables in the developed world gets closer to the end customer, progressively replacing copper cables, it has been necessary to deploy larger quantities of relatively low fibre count cable. As well as reducing the number of fibres in cables, there has been a trend to miniaturise these cables so that they can be blown into smaller tubes. A typical example of such a cable would contain 48 fibres arranged in bundles of 12 around a single central glass polymer strength member and encapsulated in a polymer jacket. The cable diameter is 5.5 mm and the cable is suitable for installation in a tube typically having 10 mm outside diameter and 8 mm internal diameter. These lightweight reinforced cables have also been developed for fibre counts as low as two fibres.

The fact that these cables are reinforced, usually to provide additional stiffness, means that a significant pushing force can be exerted and much of the installation can still be achieved by pushing rather than fluid drag.

As cables have become more lightweight and flexible, the importance of fluid drag as a means of propulsion has increased. EP 0108590 describes a fibre optic cable as small as 1 mm in diameter. Reinforcement of such small fibre optic cables is difficult, if not impossible, and in this case the installation depends largely on fluid drag as the means of propulsion and the higher the fluid drag the better is the installation performance.

Installation of the optical fibre cable by this method has the advantage of spreading the installation force across the entire surface area of that part of the cable located within the duct, and therefore minimises the risk of excessive tension forces being applied to the cable, which could damage the fragile and unreinforced optical signal transmitting part of the cable. The small diameter of these unreinforced cables has the advantage of being suitable for installation in very small tubes as small as 3 mm outside diameter, which has a major benefit when distributing fibres to a large number of individual locations. There has been considerable development of such small lightweight unreinforced cables, the objective of these developments being to provide a blowable optical fibre having excellent blow-in properties in combination with very low microbending and signal losses at low temperatures.

It is generally believed that a rough or textured external surface of the cable provides superior blowing performance. EP 0521710 describes a fibre optic cable consisting of several layers where the outer surface has been modified to obtain the benefit of increased fluid drag and reduced friction. A rough surface has the benefits of increasing the effective outside diameter without increasing the weight to the same extent as a cable of the same diameter having a smooth external surface. Increasing the effective diameter increases the fluid drag. In addition, rough surfaces intrinsically have higher fluid drag coefficients. Finally, rough surfaces reduce the contact points between the

cable and the tube and therefore reduce friction between the cable and the tube. All of these factors improve installation characteristics and blowing distances.

However, it is also well known that manufacturing cables with rough surfaces is problematic. In particular, the attachment of glass microspheres as a means of providing a rough surface is known to cause a weakening of the surface coating, which can create fibre break out, where the individual fibres break out of the coating causing micro-bending and create unacceptable signal losses. Another problem of such cables is that the micro-spheres can become detached, creating a potential hazard during installation by blowing. EP 646818 describes a method for overcoming some of the disadvantages of this manufacturing technique by means of the application of three separate layers, making the process relatively complex and therefore more difficult to control.

Another method for creating a rough outer layer is described in EP0157610, EP0296836, EP0338854 EP0422764and EP0338855.These documents describe the application of a foam polymeric material such as polyethylene or EVA as an outer layer. The foaming process produces an outer layer which is rough, relatively large in diameter and also relatively light weight in relation to its diameter. As discussed above, these are desirable properties in that the first two in particular increase fluid drag. However it has been found in practise that the blowing performance of cables with this type of construction is poor and requires the use of tubes with relatively large diameters. It is also the case that the foaming process is difficult to control, producing inconsistencies in the density of the foam which can induce micro-bending and unacceptable signal losses. For this reason, this type of product has been substantially superceded in commercial application by the products described in the prior art documents listed above.

Another method for creating a rough outer layer is described in WO01/73494, which involves braiding threads around a previously coated fibre unit. A disadvantage of this approach is that controlling the tension of each individual thread is extremely difficult and when not controlled to very tight tolerances, the tension of the threads produces micro bending of the fibres and unacceptable signal losses.

Preferred embodiments of the present invention seek to overcome the above disadvantages of the prior art.

According to the present invention, there is provided a cable assembly comprising a plurality of flexible signal transmitting members embedded in a first layer such that at least the outermost signal transmitting members are prevented from moving axially relative to said first layer, and a substantially continuous second layer arranged outwardly of said first layer and formed from a mixture of at least one polymer material and at least one friction reducing material.

The present invention is based on the surprising discovery that light weight fibre optic cables with excellent optical and blowing properties can be manufactured by providing an outer layer of the cable formed from a mixture of at least one polymer material and at least one friction reducing material, even in the case of a smooth outer layer. This avoids the complex production problems associated with the production of a rough outer surface by the application of glass microspheres, foamed thermoplastics, braided surfaces and the like. This result is surprising firstly because the high fluid drag provided by these surface modifications is regarded by those skilled in the art as essential to providing good blowing performance, and secondly because whilst the friction characteristics of the outer layer of the invention are good relative to some polymers they are inferior to the prior art as described in EP 0521710. Very surprisingly the blowing performance significantly exceeds the performance of these prior art cables.

The mixture may be compounded by means of heat and pressure.

The signal transmitting members may be arranged in a bundle.

The bundle may comprise at least one inner signal transmitting member surrounded by a plurality of outer signal transmitting members.

The outer surface of said first layer may be of substantially circular transverse cross-section.

This provides the advantage of minimising the extent to which the cable assembly has any preferred bending direction, ensuring that an equal pushing force can be applied to the fibre unit during installation irrespective of the orientation of the fibre.

The second layer may include polyethylene.

The friction reducing material may include at least one slip agent.

The friction reducing material may include at least one surface tension reducing silicone material.

The friction reducing material may include at least one polyether modified poly (dimethylsiloxane) material.

The friction reducing material may include at least one polyether modified hydroxy functional poly (dimethylsiloxane) material.

The friction reducing material may include at least one polyester modified poly (dimethylsiloxane) material.

The inner diameter of said second layer may be larger than the outer diameter of said first layer.

This provides the advantage that the outer layer can be provided in the form of a loose jacket, which can significantly improve the flexibility of the cable assembly and also make it easier to break the individual optical fibres out of the cable assembly for termination or splicing.

The second layer may be provided with irregularities on an outer surface thereof.

This provides the advantage of increasing the fluid drag between the cable assembly and fluid used to install the assembly into a duct.

The outer surface may be textured and/or patterned and/or profiled.

The friction reducing material may be distributed substantially uniformly throughout said second layer.

The second layer may include at least one said polymer material having a respective polymer backbone including silicon and/or flourine atoms.

The second layer may include at least one mineral filler.

This provides the advantage of making the second layer more dimensionally stable relative to changes in temperature.

The first layer may include at least one acrylate material.

Preferred embodiments of the invention will now be described, by way of example only and not in any limitative sense, with reference to the accompanying drawings, in which:-

Figure 1A is a schematic cross-sectional view of a fibre optic cable of a first embodiment of the present invention;

Figure 1B is a schematic cross-sectional view of a fibre optic cable of a second embodiment of the present invention;

Figure 1C is a schematic cross-sectional view of a fibre optic cable of a third embodiment of the present invention;

Figure 1D is a schematic cross-sectional views of a fibre optic cable of a fourth embodiment of the present invention;

Figure 2 is a schematic representation of apparatus for manufacturing the cables of Figure 1A to 1D;

Figure 3 is a drawing of the test equipment used to measure the coefficient of friction between cables and a tube suitable for installation of cables by blowing.

Figure 4a illustrates the speed of installation and the total installed distance of the fibre optic cable of figure 1C into a duct, compared with the performance of a prior art cable constructed with the surface modification described in EP 0521710 and EP 646818, also containing 8 fibres;

Figure 4b illustrates the speed of installation and the total installed distance of the fibre optic cable of Figure 1B into a duct, compared with the performance of a prior art cable constructed with the surface modification described in EP 0521710 and EP 646818, also containing 12 fibres; and

Figure 5 illustrates optical attenuation characteristics of the cable of Figure 1B over a wide range of temperatures.

Referring to Figures 1A to 1D, a fibre optic cable 1 includes a core of primary coated optical fibres 2, which will be familiar to persons skilled in the art, embedded in an inner layer 3 of acrylate material having sufficient tensile strength when cured to lock the fibres 2 in place and still allow the fibres to be easily broken out of the assembly for termination and splicing purposes. Suitable materials for this application are DSM Cabelite 950-706 and DSM Cabelite 3287-9-41. These materials are available from DSM Desotech BV. The hardness of the acrylate layer 3 is such that at least the outermost fibres 2 of the bundle are prevented from moving axially relative to the inner layer 3. The inner layer 3 is then surrounded by a loose thin jacket 4 formed from a mixture of polyethylene and a

generally uniformly distributed slip agent, including a polyether modified poly (dimethylsiloxane) material such as polyether modified hydroxy functional poly (dimethylsiloxane) material. The mixture from which the outer layer 4 is formed is compacted by means of heat and pressure as described below. The outer layer 4 may also contain a mineral filler, such as calcium carbonate and/or titanium dioxide, in order to improve the stability of the dimensions of the outer layer 4 as the temperature changes.

In order to manufacture the cables 1 of Figures 1A to 1D, the primary coated optical fibres 2 are supplied from a bank of payoff reels (not shown), the number of reels being equal to the number of fibres 2 to be included in the cable 1. The fibres 2 are unwound with a generally constant traction force. The fibres 2 are then bundled together into a bundle of suitable shape, and are passed through a resin application station, where an acrylate resin forming the inner layer 3 is applied to the bundle of fibres 2, the acrylate resin being a UV-curing resin. The coated assembly of fibres 2 is then pulled through a series of curing ovens which cure the inner layer 3 to the desired dimensions. The above process can be carried out, for example, using a modified fibre ribbon line provided by Nextrom, Vantaa, Helsinki, Finland.

Referring now to Figure 2, the external coating 4, formed from a mixture of polymer and friction reducing material which has previously been compounded by means of heat and pressure, is applied to the inner layer 3 of the coated optical fibre bundle described above by pulling the coated fibre bundle through a thermoplastic extrusion line as shown in Figure 2. Such a line is available from Nextrom Technologies, Nextrom S A, Route du Bois, 37 PO Box 259, CH-1024 Ecublens-Lausanne, Switzerland. The thermoplastic extrusion line 10 has a payoff stand 11 which allows the coated fibre bundle to be paid off a reel 12 at a generally steady rate. A tensioning device 13 ensures that the coated bundle is taut before entering an extrusion crosshead 14 which applies the mixture of high density polyethylene incorporating the suitable silicon slip agent to the coated bundle at a temperature between 190 °C and 230 °C.

The polyethylene coated cable is then pulled through a vacuum tank 15 which applies a vacuum to the outer coating 4 by surrounding it with water, the vacuum being between 100mbar and 50mbar, and also cools the fibre unit as it leaves the extrusion crosshead 14. Additional cooling is provided by pulling the cable through a water trough 16, the water being at a temperature of approximately 20°C. A caterpillar unit 17 pulls the fibre unit through the entire thermoplastic extrusion line 10, the cable 1 then being coiled into a pan 18 by means of a coiler 19. It will be appreciated by persons skilled in the art that the two processes described above could be arranged in a single manufacturing line and the process completed in a single stage.

Referring to Fig 3, this shows an apparatus for measuring the friction characteristics of the cables. Two cables, the first embodying the present invention (the invention) and the second a commercially available cable with the surface modification described in EP 0521710 and EP 646818 were tested to measure their coefficient of friction relative to a tube manufactured commercially for use in blown cable applications.

The test method comprises attaching a weight of 10 grammes to one end of the cable and threading the other end through tube 101, round pulley 102, through tube 103 and then through a length of tube 104. The tube 104 is a commercially available tube with outside diameter 5mm and internal diameter 3.5mm manufactured for receiving installation of cables by blowing. The tube 104 is wrapped around a wheel 105 to provide a total of 450 degrees of wrapping. After the cable has been threaded through the tube 104 it is then inserted into a haul off 106 which pulls the cable at a constant speed of 10 metres per minute. The tube 104 is clamped at both ends by clamps 107 and as the cable is pulled through the tube 104, the friction of the cable on the tube imposes a turning moment on the wheel 105 and rotates a lever 108 which imposes a load on a mass balance 109.

The load on the mass balance 109 was measured for both the invention and the prior art and the coefficient of friction calculated using the formula :

Coefficient of friction is given by

$$\mu = \frac{1}{\theta}\ln\left[\frac{FL}{Tr}+1\right]$$

Where

θ	total wrap angle of tube (rads)
F	force recorded at mass balance (N)
L	Moment arm length of force F (m)
T	Weight lifted by fibre (N)
r	Bend radius of primary tube (m)

The cable of the invention had a coefficient of friction of 0.27 whilst the cable of the prior art had a coefficient of friction of 0.21. The friction characteristics of the invention are therefore inferior compared to those of the prior art.

Referring now to Figures 4a and 4b, the blowing performance of the cable, manufactured according to the above process is assessed by measuring the speed of installation and the total distance installed of the fibre unit into a suitable duct. The comparison involves an industry standard test in which 500 metres of a commercially available tube with outside diameter 5mm and internal diameter 3.5mm manufactured for receiving installation of cables by blowing, is wound onto a drum with barrel diameter of 500 mm.

In the case of Fig 4a, two fibre optic cables, the first being the cable of Figure 1C (curve A) and the second a commercially available cable with the surface modification described in EP 0521710 and EP 646818 (curve B) are compared. Each of the cables contained 8 fibres arranged in their respective coatings. The cables of prior art and the invention were blown into the tube using industry standard blowing equipment, compressed air at 10 bar pressure and techniques identical for both cables.

In Figure 4a, the blowing performance of the the two cables is compared. It can be seen that the prior art product started to slow down after only 250 metres had been installed. At 430 metres the installation speed had declined to only 10 m/min. The cable of the

invention, on the other hand, completed the test route at a constant speed of 24 m/min. In Figure 4b the comparison is repeated except that this time the cables each contained 12 fibres, i.e. the cable of the invention is the cable of Figure 1B. In this case the prior art cable (curve D) installed just 24 metres before stopping completely whilst the cable of the invention (curve C) completed a distance of 375 metres before stopping.

The blowing performance of Figures 4a and 4b represents a substantial and unexpected improvement compared to the prior art, particularly so in view of the fact that the cable of the invention has inferior friction properties and has a surface which had not been physically modified in any way to enhance fluid drag.

Referring now to Figure 5, the signal loss over a wide temperature range associated with cables manufactured according to the above process is shown. The different curves show signal attenuation in the individual fibres 2 of the cable of Figure 1B. It can be seen that the cable 1 can withstand exposure to a wide temperature range. This is a surprising result. Prior art cables as described in EP0157610 incorporating polyethylene outer layers display poor optical performance below approximately –20°C. This is usually attributed to a change of phase in polyethylene at around this temperature and for this reason polyethylene is not normally selected for the tight jacketing of fibre optic elements.

It will be appreciated by persons skilled in the art that the above embodiments have been described by way of example only, and not in any limitative sense, and that various alterations and modifications are possible with departure from the scope of the invention as defined by the appended claims. For example, as an alternative to, or in addition to, the friction reducing materials described in the above embodiments, erucamide and/or oleamide materials may be used as slip agents.

CLAIMS

1. A cable assembly comprising a plurality of flexible signal transmitting members embedded in a first layer such that at least the outermost signal transmitting members are prevented from moving axially relative to said first layer, and a substantially continuous second layer arranged outwardly of said first layer and formed from a mixture of at least one polymer material and at least one friction reducing material.

2. An assembly according to claim 1, wherein the mixture is compounded by means of heat and pressure.

3. An assembly according to claim 1 or 2, wherein the signal transmitting members are arranged in a bundle.

4. An assembly according to claim 3, wherein the bundle comprises at least one inner signal transmitting member surrounded by a plurality of outer signal transmitting members.

5. An assembly according to any one of the preceding claims, wherein the outer surface of said first layer is of substantially circular transverse cross-section.

6. An assembly according to any one of the preceding claims, wherein the second layer includes polyethylene.

7. An assembly according to any one of the preceding claims, wherein the friction reducing material includes at least one slip agent.

8. An assembly according to any one of the preceding claims, wherein the friction reducing material includes at least one surface tension reducing silicone material.

9. An assembly according to any one of the preceding claims, wherein the friction reducing material includes at least one polyether modified poly (dimethylsiloxane) material.

10. An assembly according to any one of the preceding claims, wherein the friction reducing material includes at least one polyether modified hydroxy functional poly (dimethylsiloxane) material.

11. An assembly according to any one of the preceding claims, wherein the friction reducing material includes at least one polyester modified poly (dimethylsiloxane) material.

12. An assembly according to any one of the preceding claims, wherein the inner diameter of said second layer is larger than the outer diameter of said first layer.

14. An assembly according to any one of the preceding claims, wherein the second layer is provided with irregularities on an outer surface thereof.

15. An assembly according to claim 14, wherein the outer surface is textured and/or patterned and/or profiled.

16. An assembly according to any one of the preceding claims, wherein the friction reducing material is distributed substantially uniformly throughout said second layer.

17. An assembly according to any one of the preceding claims, wherein the second layer includes at least one said polymer material having a respective polymer backbone including silicon and/or flourine atoms.

18. An assembly according to any one of the preceding claims, wherein the second layer includes at least one mineral filler.

19. An assembly according to any one of the preceding claims, wherein the first layer includes at least one acrylate material.

20. A cable assembly substantially as hereinbefore described with reference to the accompanying drawings.